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MANUFACTURING CONTROLS  
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## MANUFACTURING CONTROLS

### OBJECTIVE

Throughout this guide, the manufacturing management functions are discussed within the context of the defense systems acquisition process. Government policies, requirements, and guidance are described to ensure that the program managers, and their support personnel, are aware of the many interrelations involved in this important discipline.

This chapter concentrates on the manufacturing controls necessary to ensure that the type of problems listed in Figure 13-1, which are symptomatic of the complex manufacturing environment, do not disrupt the acquisition program. While Figure 13-1 is far from exhaustive, these problems exist in many manufacturing plants. Thus, manufacturing surveillance can assist the program manager in determining progress in meeting milestones and delivery schedules, and identifying factors that may adversely impact delivery, performance or cost.

- **INVENTORY INVESTMENT IS EXCESSIVE, YET THERE ARE SHORTAGES OF NEEDED MATERIAL**
- **CRASH PROGRAMS TO REDUCE INVENTORY INVESTMENT TO SOME ARBITRARY LEVEL OCCUR FREQUENTLY AND ARE BASED ON EDICTS**
- **DELIVERY DATES ARE OFTEN MISSED AND OVERTIME IS USED TO MEET NEW NEED DATES**
- **PRODUCTION CONTROL, PURCHASING, PLANT SUPERVISORY PERSONNEL AND OTHERS ARE IN CONSTANT MODE OF EXPEDITING**
- **MANY MANUFACTURING AND PURCHASE ORDERS ARE PAST DUE BUT ARE NEEDED TO FILL CURRENT SHORTAGES**
- **WORK IN PROGRESS IS CLOGGING THE SHOP FLOOR AND MANUFACTURING ORDERS ARE SOMETIMES LOST, ALBEIT TEMPORARILY**
- **REJECTED MATERIAL ACCUMULATES AND ITS DISPOSITION IS USUALLY MADE WHEN A PART IS SHORT ON THE ASSEMBLY FLOOR**
- **THERE IS A LACK OF RAPPORT AND COMMUNICATION AMONG PRODUCTION CONTROL, INVENTORY CONTROL, PURCHASING, SALES, ENGINEERING, DATA PROCESSING, ACCOUNTING, AND SHOP FLOOR PERSONNEL**
- **BILLS OF MATERIAL AND ROUTING AND INVENTORY RECORDS ARE INACCURATE OR INCOMPLETE**
- **OVERHEAD COST LEVELS ARE EXCESSIVE BECAUSE CURRENT PLANNING AND CONTROL SYSTEMS ARE NOT TIMELY**
- **PRODUCTIVITY IS LOW BECAUSE OF EXCESSIVE SHORTAGES, CAUSING IDLE TIME AND FREQUENT EQUIPMENT CHANGEOVERS**
- **DATES ON WHICH ENGINEERING CHANGES BECOME EFFECTIVE ARE NOT HIGHLY VISIBLE TO EVERYONE AND CONFIGURATION CONTROL IS LOST**
- **THE MAJORITY OF SHIPMENTS ARE MADE DURING THE LAST WEEK OF THE MONTH**

**Figure 13-1 Typical Manufacturing Problem Areas**

Control of the manufacturing system is critical to ensuring that high quality products are produced on-time and at reasonable cost. A well defined management system needs to be established and implemented within the factory and supporting organizations. As the manufacturing system is accomplishing the production task, control systems must exist to identify variances from plans or targeted performance. These variances alert management to take action to correct the causes of the problems before major program impact results.

#### MANUFACTURING MANAGEMENT SYSTEM EVALUATION

Manufacturing resources consist of facilities in which equipment, human resources, and capital convert raw materials and component parts into end products for internal or external users. Contractors must have an effective combination of people and systems in order to plan and control these manufacturing resources. The government, in recognition of this objective, requires contractors to implement proven manufacturing control systems which, when properly implemented and managed, lead to successful manufacturing management.

##### Scope and Functions

The degree of program management involvement with manufacturing operations is predicated upon the importance of the specific product. Manufacturing directly impacts both cost and DOD capability. Unnecessarily high cost due to manufacturing inefficiency may be reflected in the reduction of vitally needed weapons and equipment. Acquisition programs often are constrained to a specific total expenditure. If manufacturing costs increase, typically the expenditure constraint causes a reduction in the number of systems acquired, which results in a negative impact on DOD capability to achieve its operational objectives. Manufacturing inefficiency also reduces the capability of the industrial base to respond to basic DOD needs as well as surge and mobilization. Regardless of the type of contract involved, the manufacturing management effort including program office, contract administration, and contractor involvement, must be structured to meet defined program objectives related to efficiency, capacity and capability.

Government manufacturing engineers and industrial specialists are the individuals primarily concerned with surveillance of the contractor's accomplishment of the manufacturing objectives and with the efficiency and economy of manufacturing operations. This requires the consideration of a wide range of issues involving manufacturing planning and control, personnel and equipment scheduling and loading, production equipment maintenance, in-process inventory control, analysis of manufacturing operations, scrap prevention, and manufacturing management techniques.

##### Manufacturing Operations

Manufacturing management involves planning for, controlling and executing manufacturing operations. Accomplishing manufacturing objectives requires that the contractor establish basic manufacturing policies, implement those policies through manufacturing procedures, and develop detailed work instructions. In evaluating the contractor's ability to attain such objectives, the following questions can serve as a basis for the DOD evaluation:

- a) Are the contractor's manufacturing objectives and assignment of responsibilities satisfactorily described in policies and implementing procedures?
- b) Does the contractor have a system for establishing functional performance goals, measuring performance against goals and identifying causes for failures to achieve goals?
- c) Are manufacturing plans and procedures designed so that personnel requirements can be determined by number, skills, and training?
- d) Are the contractor's internal audit practices and procedures designed to identify manufacturing management deficiencies and is there a requirement for prompt corrective action?

It must be emphasized that manufacturing management evaluation is system oriented. While each of the parts comprising the manufacturing operations system may be individually acceptable, contractor integration of the parts is critical to overall success.

### PERFORMANCE EVALUATION

Performance evaluation includes the periodic examination of the contractor's efforts to perform the contract; appraisal of the extent to which these efforts have moved forward toward completion of the total effort; and a judgment of the probability of the total effort being completed as required by the agreement (the contract).

The kind of performance evaluation, and the depth and extent of the evaluation, depend upon a variety of considerations. The program office must assess these variables in order to determine the actions necessary and appropriate to enhance the probability of successful contract performance.

The evaluator must determine the importance of the contract activities being evaluated in order to arrive at an order of magnitude of surveillance effort and the priority of that effort. This decision should be influenced by:

- a) The size of the program in terms of:
  - length of time
  - estimated cost
  - extent of the effort involved.
- b) The significance of the effort in relation to overall organization objectives.
- c) The nature and complexity of the work.
- d) The type of contractual relationship.

The kind and degree of surveillance and evaluation will also depend upon the degree of certainty or uncertainty associated with the extent of the contract work. Associated with this is the confidence that the government and the contractor have in the estimate of the amount of effort that is necessary to accomplish the contract task within the time and technical constraints.

### Progress Evaluation

Most of the effort in performance evaluation focuses on the technical aspects of the work to identify foreseeable technical problems as they bear on the extent of work. In research and development work, the contract effort itself is concerned with the advancing of the state of knowledge. A clear statement of what is to be accomplished, expressed in terms that can be measured, is a necessary requirement for planning a research or development program. When the objective is explicitly expressed the technical or internal uncertainty of a program can be identified; experimental procedures, scientific or engineering skills determined; and work plan developed with subtasks identified which will be most effective in achieving the R&D objective. In research and development, measuring the achievement against a standard of performance for the technical objective is possible when each of the subtasks is identified and the program objective clearly stated.

The status of study and experiment for a research contract is often hard to gauge before completion. Objective scheduling criteria may be minimal; parameters may be broad and flexible. Researchers may encounter breakthroughs or setbacks that negate earlier progress data. Research or development program difficulties of this nature cannot be eliminated but can be significantly reduced with a well developed work plan. In research contracts, monitoring consists largely of evaluation of the technical aspects of a program along with planned schedules. The other main progress controls are costs incurred and the contractor's level of effort and accomplishment.

Progress measurement becomes easier in the developmental phase of acquisition. Though the work is not

yet repetitive and detailed specifications are still not completely formulated, much of the indefiniteness of research is gone. The experience gained on earlier contracts should provide some standard for comparison. However, success still depends on the contractor's ability to cope with obstacles not met before. Thus, technical evaluation is still very important in determining the status of development work.

On production contracts, the end item design is reasonably firm. The manufacturing process and a manufacturing schedule are established at the outset of the procurement. Technical evaluation is not paramount since the product design is relatively fixed. The emphasis shifts to the more usual production control and financial status data.

#### Monitoring Contractor Progress

The purpose of monitoring progress is to obtain the information the government needs about a particular procurement. Monitoring may disclose defects in the contractor's system and, in turn, show the need for monitoring subcontract performance. Monitoring provides a variety of information serving many purposes:

- Providing up-to-date delivery information;
- Helping determine the adequacy of the contractor's own monitoring system;
- Helping to identify and isolate contractor performance problems;
- Generating data on cost of specific areas of performance (these data are often needed for cost analysis of change orders, or approval of progress payments in certain type contracts);
- Identifying the need to allocate government property to various programs requiring it;
- Aiding in making an early decision about when to incorporate new components in major equipment;
- Determining the government's rights under the contract — for instance, when questions of default arise;
- Determining future funding requirements by comparing actual cost with accomplishments.

Progress information comes from many sources; however, the primary ones are: schedules, monthly cumulative progress reports, material inspection and receiving reports, special progress reports, and cost performance reports or cost/schedule status reports.

The contractor may be required to submit a phased schedule for review by the government. This requirement appears in the Statement of Work and the Contract Data Requirements List (CDRL). These schedules usually show the time required to perform the fabrication cycle of planning, purchasing, plant rearrangements, tooling, component manufacture, subassembly and final assembly, testing, and shipping. The degree to which each function is subdivided depends on considerations of the nature of the end item, the type of fabrication process, the size and complexity of the contractor's organization, and the established schedule. The approved schedule serves as a basis for reporting and measuring contract performance.

The monthly progress report is used to obtain performance progress information from contractors. On this report the contractor shows actual and forecast deliveries (as compared with the contract schedule); delay factors, if any; and the status of prefabrication work (design and engineering facilities, tooling; receipt of government furnished property (GFP) and construction of prototypes. These data are shown in terms of scheduled and estimated starting and completion dates and percentage of completion. The report form should also contain narrative sections. The contractor uses these sections to explain any difficulties, or delay factors, action taken or proposed to overcome these difficulties, and any assistance required from the government.

#### Financial Progress Information

For other than FFP contracts, effective program management depends on receiving cost information and

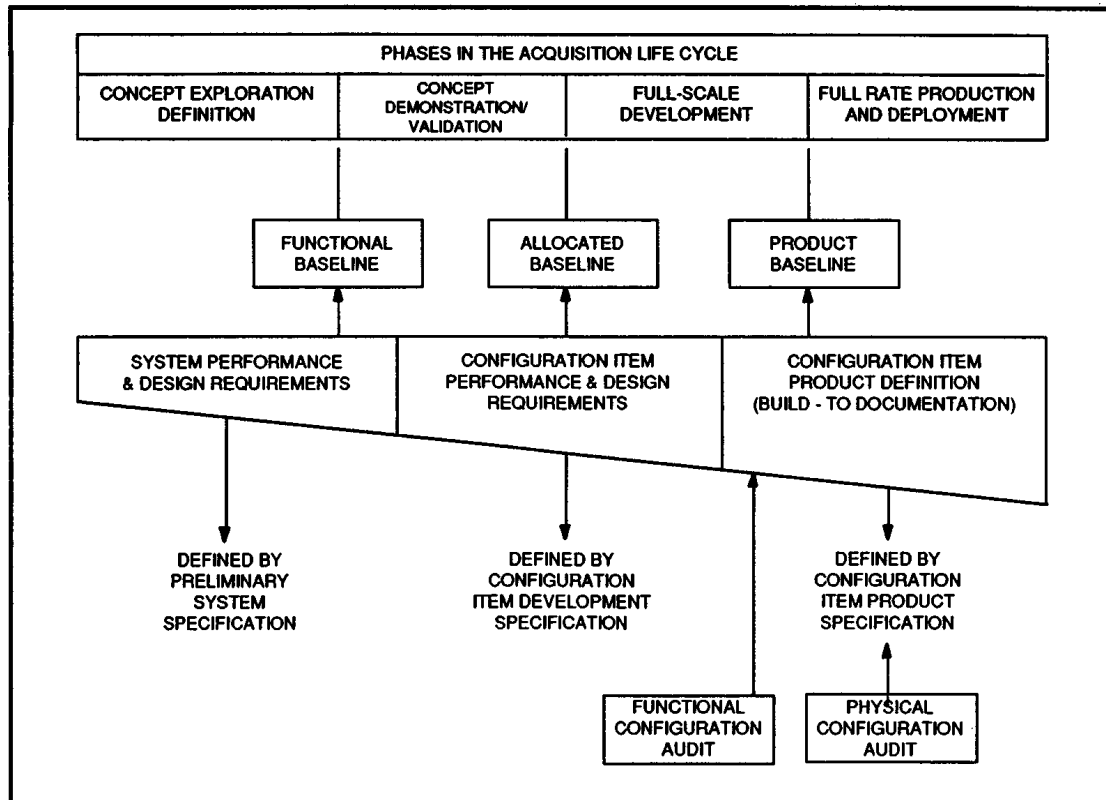
ensuring that the contractor's system is capable of generating timely and accurate cost information. The financial data furnished by the contractor normally includes: cumulative expenditures on the contract, forecasts of future expenditures and commitments, and an estimate of the total costs at contract completion. This information helps in forecasting cost underruns or overruns on cost reimbursement and fixed-price-incentive contracts. Cost performance reports (CPR) and the cost/schedule status report (C/SSR) provide the bases for measuring the contractor's overall performance on the contract.

In evaluating cost information, the rate of expenditure can be compared with the percent completion. On cost reimbursement contracts, costs should, as a rule, be assessed against individual work elements, even though the cost limitation applies to the entire job. Looking at progress from this standpoint should give a picture of the status of the work and indicate any special problems that might exist.

### CONFIGURATION MANAGEMENT

The configuration management (CM) discipline spans the product life cycle and contributes toward ensuring sustained system performance, minimizing the effects of design changes — functional or physical — reducing the incidence of system incompatibility, and avoiding the procurement of obsolete spare parts during the provisioning process. In order to relate configuration management to manufacturing management, a number of definitions are provided.

Configuration means the physical and/or functional characteristics of hardware and software as set forth in technical documentation and achieved in a system or component. Configuration management, then, can be defined as a discipline applying technical and administrative direction and surveillance to identify and document the functional and physical characteristics of a configuration item; to control changes to those characteristics, and to record and report change processing and implementation status. These simple words describe a complex process essential to the successful management of a production program and highlight three major areas of effort — identification, control, and status accounting — comprising the configuration management discipline. Figure 13-2 shows the relationship between configuration management and the product development cycle.



**Figure 13-2 Configuration Management by Baselines**

Two other concepts should be mentioned - configuration items and baselines. The basic unit of configuration management is the configuration item (CI) which is defined as an aggregate of hardware/computer programs, or any of their discrete portions, which satisfy end-use functions.

This breakdown of CIs is critical to successful application of the configuration management discipline and impacts performance and functional compatibility of the weapon system sub-elements. Specifications must be prepared to document the characteristics of each CI; design reviews and audits must be performed for each CI; engineering change proposals are prepared individually for each CI; and status accounting tracks the implementation of changes to each CI.

The second concept — baselines — refers to the authorized and documented technical description specifying the functional and physical characteristics of a system/component. Functional characteristics describe the performance requirements the item is expected to meet. Physical characteristics relate to the material composition and dimensions of the manufactured item. An item is governed primarily by the intended functional characteristics during development. As the item enters production, it should be defined in terms of its physical characteristics with full consideration for material requirements, part tolerancing, quantities to be produced and delivery schedule. It becomes obvious that the configuration management process must be tailored to a number of configuration item factors — program size, complexity, life cycle state — and the fact that no single set of management procedures will meet every program need. Since the physical design evolves from the system performance design requirements, it is necessary to control both the functional and the physical configuration. This is accomplished through configuration baseline management.

Baseline management deals with defining and documenting, for each configuration item, the system

requirements and the requirements for each CI. These baselines reflect the development status and are intended to control the implementation of system changes while retaining design and development flexibility. The translation of technical requirements in a baseline management function permits contracting for needed engineering and production support (producibility, risk analyses, process development, tool design, testing, inspection) in a clearly definable, priceable and manageable progression.

Three baselines are generally considered in configuration management. These are the functional, allocated, and product base lines. The functional baseline is the initial baseline and is defined by the system specification prepared during the concept exploration phase. As the system specification is expanded and refined, contractor specifications are prepared for all new configuration items comprising the total system configuration. These development specifications define the allocated baseline for the system CIs. As the program proceeds through full-scale development, system as well as CI design and development continues and results in item product specifications. The product specification then becomes the product baseline for use during production.

Figure 13-2 is intended to summarize visually those configuration management areas of specific interest to the program manager. During each phase, configuration management decisions will be required. These decisions impact both the weapons system and manufacturing process designs and are critical to the attainment of program objectives.

#### Policies and Objectives

DOD has established policies and guidance governing the configuration management of systems/components. MIL-STD-490 covers specification practices (configuration identification). DOD-STD-480A and MIL-STD-481 cover configuration control and establish requirements for submitting engineering change proposals (ECPs) deviations, and waivers, as well as the amount and type of information that should be included in the submittals. Finally, MIL-STD-482 provides guidance on configuration management status accounting. In addition to these primary standards, there are numerous DOD and Service documents highlighting associated areas including contractual requirements for those areas not included in the basic standards.

#### Configuration Identification

Configuration Identification (CI) is defined as the current or conditionally approved technical documentation of an item as set forth in specifications, drawings and associated lists, and documents referenced therein. Configuration identification is established by baseline configuration identification documents and all affected changes. Configuration identification documents include all those necessary to provide a full technical description of the characteristics of the item that require control at the time that the baseline is established.

Functional Configuration Identification (FCI) (functional baseline and approved changes) will normally include a Type A, system specification, or a Type B, product specification supplemented by other specification types as necessary to specify: (1) all essential system functional characteristics; (2) necessary interface characteristics; (3) specific designation of the functional characteristics of key configuration items; and (4) all of the tests required to demonstrate achievement of each specified characteristic.

Allocated Configuration Identification (ACI) (allocated base line and approved changes) normally consists of a series of Type B specifications defining the functional requirements for each major configuration item. These may be supplemented by other types of specifications, engineering drawings and related data, as necessary, to specify: (1) all of the essential configuration item functional characteristics, including delineation of interfaces; (2) physical characteristics necessary to assure compatibility with associated systems, configuration items and inventory items; and (3) all of the tests required to demonstrate achievement of each specified functional characteristic.

#### Configuration Audits

Two kinds of configuration audits are performed — functional and physical. Functional configuration audits represent the formal examination of the CI's functional test data, before acceptance of the development effort, to verify that the item has achieved the performance specified in its functional or allocated configuration identification. The functional configuration audit also verifies that the CI's technical documentation accurately

reflects the CI's functional characteristics and the documentation of the physical configuration from which the test data was obtained. This is necessary for determining the adequacy of production acceptance tests.

The physical configuration audit represents the formal examination of the "as built" configuration of a CI against its technical documentation. The physical configuration audit helps ensure that the production acceptance testing requirements are adequate and includes a detailed audit of engineering drawings, specifications, computer program listings, flow charts, and other technical data used in producing hardware and computer program CIs. This audit typically occurs at selected points after the development phase and involves first production items, new production after a long break in production, contractors producing a CI for the first time and first production units of a significantly changed CI. It should be recognized that the product specification must be available to the program office in sufficient time to plan the audit.

Configuration audits and system engineering design reviews are complementary. The purpose of the configuration audits and engineering design reviews is to validate the contractor's system design and test engineering efforts while progressive increments of the configuration identification and test documentation are being generated.

#### Configuration Control

Configuration control is the systematic evaluation, coordination, approval, and implementation or disapproval of all changes in the configuration of a system or end product after formal establishment of its configuration identification. Simply stated, configuration control maintains the functional, allocated, and product CI baselines and regulates all changes thereto. Change control prevents unnecessary or marginal engineering changes while expediting the approval and implementation of those that are necessary or offer significant benefits.

Both DOD-STD-480A and MIL-STD-481 delineate configuration control requirements and provide instructions for preparing and submitting proposed engineering changes and related information. One of the two standards, DOD-STD-480A, covers the broader area and requires a more complete analysis of the impact if the engineering change described by an engineering change proposal (ECP) were implemented. DOD-STD-480A requires that the data package submitted with an ECP contain a description of all known interface effects and information concerning changes required in the functional, allocated and product configuration identification (FCI/ACI/PCI). It is intended that DOD-STD-480A be imposed on prime contractors who (1) have participated or are participating in the engineering or operational systems development of a system or high level CI, or (2) are being supplied with copies of the system specification and/or development specification(s), or (3) have extensive experience in the preparation of ECPs relative to high level CIs. Such contractors have the capability of providing to the government the majority of the information needed to properly evaluate the merits of a complex engineering change, possibly involving interrelated changes in other CIs. DOD-STD-480A also covers requirements for submittal of deviations, waivers and notices of revision (NORs).

MIL-STD-481 is intended for use in contracts involving either multi-application items not peculiar to specific systems or procurement from a contractor who cannot reasonably be expected to know all of the consequences of an engineering change. An example of such a contractor is one who is required to fabricate an item to a PCI which he did not prepare, or one who did not participate in engineering development and hence is not familiar with requirements of the system or higher level CI. When MIL-STD-481 rather than DOD-STD-480A is prescribed, the major portion of the analysis of the impact of an ECP on associated items is transferred from the contractor to the procuring activity.

#### Configuration Status Accounting

Configuration status accounting is defined as the recording and reporting of the information that is needed to manage configuration effectively, including a listing of the approved configuration identification, the status of proposed changes to configuration, and the implementation status of approved changes.

Configuration status accounting represents the process of recording the documented changes to an approved baseline and results in the maintaining of a continuous record of the configuration status of the individual CIs comprising the system. Additionally, valuable management information concerning both required and

completed actions resulting from approved engineering changes is provided. Status accounting information includes an index consisting of the approved configuration and a status report detailing the current configuration. All items of the initially approved configuration are identified and tracked as authorized changes to the baseline occur.

### MEASURES OF CONTRACTOR EFFECTIVENESS

During the production phase of the product life cycle, some measures of the effectiveness of the manufacturing organization should be established. The objective of this phase is to produce, in a timely fashion, systems and equipment which conform to the technical documentation at a minimum cost. Measures of effectiveness for each of these areas should be established, and performance tracked against the measure to identify opportunities for improvement for the manufacturing organization.

#### Time Measures

When a delivery schedule has been established, the effectiveness of the manufacturing organization to meet that schedule should be evaluated. In most DOD acquisitions, the delivery schedule is integrated with deployment and training schedules and failure of the manufacturing organization to achieve and maintain schedule can have significant impact on the operational forces. Schedule attainment also tends to be a rather visible program element and is often used as a measure of program status by the DOD and Service Headquarters as well as Congress and the public. In evaluating schedule performance, the fundamental issue is on-time delivery of acceptable end items to the government. In many cases, the program office will be unwilling to measure only past or current performance against the end item delivery schedule. Generally, the PM should establish, or have the contractor establish, some system which will support projections of schedule attainment in future periods. This provides an opportunity to take actions to minimize the impact of delays on the deployment process. A very useful tool for this future perspective is the Line of Balance (LOB) technique which is discussed in detail later in this chapter.

#### Conformance Measures

When systems or equipments are presented for customer acceptance, it is generally assumed that they meet the technical requirements. Many times, this assumption does not reflect reality. Equipment is presented accompanied by waiver and/or deviation requests (or approved waivers or deviations). There are also departures from technical documentation below the level of the government's configuration control which are handled by Material Review Board (MRB) action. Reducing the number of these occurrences is a basic element of a strong Total Quality Management (TQM) program.

#### Cost Measures

Manufacturing cost estimates are normally based on the assumption that the design is fully specified and that the manufacturing process will be relatively straightforward with operations being successfully accomplished as planned. Consequently, any deviation from this plan indicates the potential for cost problems. As such, time and conformance measures can give some indication of cost aberrations since there is normally a direct correlation between late delivery or conformance problems and cost. In addition, the following measures may also indicate the existence of cost problems:

- 1) Scrap and rework rates,
- 2) Percentage of out-of-station work,
- 3) Engineering change volume,
- 4) Yield rates on manufacturing operations, and
- 5) Reliability growth profiles.

These indicators do not replace normal management control systems but can be used as supplementary

information or aids in predicting and isolating causative factors. They are also valuable measures in assessing the effectiveness of the contractor's TQM program.

## WORK MEASUREMENT

Work measurement is an important tool which can be of great value in cost estimating, production planning, and contract management. A work measurement system uses engineered labor standards in most phases of the manufacturing operation. A labor standard describes the time allowed for a normally skilled operator following a prescribed method, working at a normal all-day level of effort, to complete a defined task with acceptable quality. An engineered standard is one established using a recognized technique, such as time study, predetermined time system, standard data, or work sampling to derive at least 90% of the total time associated with the labor effort covered by the standard. Non-engineered standards are those not meeting the above criteria and are usually determined by estimates or based on historical data.

### DOD Policy

The use of approved work measurement systems (WMS) is required for all production contracts for major weapon systems and subsystems costing more than \$20 million annually or a total of \$100 million. WMS may also be required on full-scale development contracts over \$100 million.

WMS should be tailored to the requirements of individual programs. Several categories of contracts are specifically exempted from the requirement. These include contracts that:

- 1) Procure commercial or non-developmental items;
- 2) Have low volume, non-repetitive production runs, such as ship construction and ship systems;
- 3) Do not require the submission of certified cost or pricing data; or
- 4) Will not realize a cost benefit as a result of WMSs; however, the cost-benefit decision must be documented and approved.

In addition, the WMS should be compatible with existing contractor technical and management processes and procedures, such as the principle of continuous improvement of the total quality management process. If WMS is required, DOD policy also requires that established WMS be actively used in contract and program management.

- 1) WMS data must be considered in contract pricing objectives and contract negotiation.
- 2) WMS must be used to provide data for use in planning, cost estimating, and monitoring contract performance in all appropriate contracts.

### Objectives

Experience has shown that excess personnel and lost time can be identified and reduced through WMS application. Furthermore, continued method improvements can be more easily identified and implemented.

Work measurement and the reporting of labor performance are not considered ends in themselves, but a means to more effective management. When properly understood and used by management, the benefits described in Figure 13-3 typically accrue from an effective WMS.

- **GREATER OUTPUT FROM A GIVEN AMOUNT OF RESOURCES**
- **LOWER UNIT COSTS BECAUSE PRODUCTION IS MORE EFFICIENT AT ALL LEVELS**
- **REDUCING WASTED TIME IN PERFORMING OPERATIONS**
- **CONTINUED ATTENTION TO METHODS AND PROCESS ANALYSIS BECAUSE OF THE NECESSITY FOR ACHIEVING IMPROVED PERFORMANCE**
- **IMPROVED BUDGETING AND COST ESTIMATING**
- **IMPROVED BASIS FOR PLANNING FOR LONG-TERM PERSONNEL, EQUIPMENT, AND CAPITAL REQUIREMENTS**
- **CONTINUAL CONTROL ACTIVITIES AND DELIVERY TIME ESTIMATES**
- **HELP IN SOLVING LAYOUT AND MATERIAL HANDLING PROBLEMS BY PROVIDING ACCURATE FIGURES FOR PLANNING AND UTILIZATION OF SUCH EQUIPMENT**

**Figure 13-3 Benefits of Work Measurement Systems**

### Measurement System

Current contracting regulations do not require the specific use of MIL-STD-1567A. Defense Acquisition Circular (DAC) 88-5 states that either the military standard or a contractor's own WMS may be used, provided the latter is acceptable to the government. However, MIL-STD-1567A is frequently cited as an example of an acceptable WMS. MIL-STD-1567A establishes certain requirements which must be met for a contractor's work measurement system to be considered acceptable. These requirements are intended to permit maximum contractor flexibility in the application to the standard, rather than providing rigid methodology by which work measurement should be accomplished. The contractor's WMS must be documented and include the elements described in Figure 13-4.

- **WORK MEASUREMENT PLAN AND SUPPORTING PROCEDURES**
- **CLEAR DESIGNATION OF THE ORGANIZATION AND PERSONNEL RESPONSIBLE FOR EXECUTING THE SYSTEM**
- **PLAN TO ESTABLISH AND MAINTAIN ENGINEERED LABOR STANDARDS OF A KNOWN ACCURACY**
- **PLAN OF CONTINUED IMPROVED WORK METHODS IN CONNECTION WITH THE ESTABLISHED LABOR STANDARDS**
- **PLAN FOR THE USE OF LABOR STANDARDS AS AN INPUT TO BUDGETING, ESTIMATING, PRODUCTION, PLANNING, AND TOUCH LABOR PERFORMANCE EVALUATION**

**Figure 13-4 Elements of a Contractor's Work Measurement System**

Specific MIL-STD-1567A requirements set goals for coverage, accuracy, allowance development, realization factor development, and WMS review. Realization factor development and analysis are particularly important, because it is the realization factor that is used to compare the WMS ideal to what is actually happening on that plant floor. Identification and elimination of inefficiencies is a vital element of WMS application.

MIL-STD-1567A also covers the use of trade-off analyses relating savings attainable through improved productivity and simplification of work methods to the cost of developing engineered standards, schedules for conversion of non-engineered to engineered standards, use of touch labor standards in the development of price proposals, contractor generated change order proposals or for estimating the prices of initial spares and replenishment spares, and production count methods to ensure accurate measurement of the work completed.

### COST/SCHEDULE CONTROL SYSTEM CRITERIA

The Cost/Schedule Control Systems Criteria (C/SCSC), are a set of criteria which describe the capabilities

which must be present for a contractor's cost and schedule control systems to be acceptable for use on contractors for major programs. The objectives of C/SCSC are twofold:

- For contractors to use effective internal cost and schedule management control systems, and
- For the Government to be able to rely on timely and auditable data produced by those systems for determining product oriented contract status.

The C/SCSC are not a management control or an accounting system. Due to variations in organizations, products, and working relationships, it is not feasible or prescribe a universal system for cost and schedule controls. Therefore, the DOD adopted an approach to identify general criteria that contractor's management control systems must meet.

The criteria are intended to be general enough to allow their use in evaluating development, construction and production contracts. Since these contracts differ significantly, it is unwise to specify detailed guidance applicable in every circumstance. Use of the criteria must be based upon common sense and practical interpretations that maintain the capabilities for adequate performance measurement.

Uniform implementation of the criteria will avoid imposing multiple cost and schedule systems on contractors. Application of management control systems acceptable to both the DOD and contractor to contracts at a given contractor's facility, will provide a common source of information for all management levels.

#### DOD Requirements and Guidelines

DODI 7000.2, first issued in 1967, requires that on major contracts, contractors use management control systems that comply with the C/SCSC. Major contracts are defined jointly by the Military Departments as: \$40 million or more or R&D, \$160 million or greater for procurement; and subcontractors that exceed \$25 million for R&D, \$60 million for procurement. This dollar amount is expressed in current/then year figures and includes the "full" planned value of the contract, including options.

The C/SCSC will not be construed as requiring the use of specific systems or changes in accounting systems that will adversely affect: the equitable distribution of cost to all contracts, or compliance with the standards, rules and regulations issued by the Cost Accounting Standards Board. Further, it is not intended to affect the basis on which contract funding or cost reimbursements are paid.

The contractor's management control system must provide data that: (a) relate time phased budgets to specific contract tasks and/or statements of work; (b) indicate work progress; (c) properly relate cost, schedule and technical accomplishment; (d) are valid, timely and auditable; (e) supply managers with information at a practicable level of summarization; (f) are derived from the same internal management control systems used by the contractor to manage the contract.

C/SCSC improves on the budget vs. actuals (spend plan) management technique by requiring that work progress be quantified through "earned value", an objective measure of how much work has been accomplished on the contract. The C/SCSC require the contractor to plan, budget, and schedule authorized effort in time phased increments that form a performance measurement baseline (time-phased budget). As work is accomplished, the earned value concept allows comparisons to be made against the plan which identifies schedule and cost variances.

The schedule variance (SV), compares the budgeted value of work accomplished (earned value) to the budgeted value of the work scheduled to be done, i.e., a difference from the plan expressed in budget (\$) terms. Likewise, a comparison of earned value against the actual costs generated to do the work provides a measure of the cost variances, i.e., the amount of cost under or overrun from the plan for the work accomplished. Planned or scheduled value of work, earned value, and the actual cost of work performed provide an objective measure of performance, thus enabling a performance trend analysis to be done and cost estimates at completion to be developed at various levels of the contract.

In addition to emphasizing the concept of earned value, the C/SCSC requires thorough integrated contract planning, realistic baseline establishment and control, performance information to be segregated by both product and performing organization, and that measurement of accomplishment at relatively low levels within the contract be summarized and provided to higher management.

### Work Breakdown Structure

The task of defining the contract work is accomplished through the use of a work breakdown structure which is essentially a “family tree” subdivision of work to successively lower levels of detail. Figure 13-5, extracted from MIL-STD-881A, Work Breakdown Structures for Defense Material Items defines three levels of identification. The PMO, in conjunction with the contractor, determines the upper levels of this WBS, which serve as the summary level for reporting purpose.

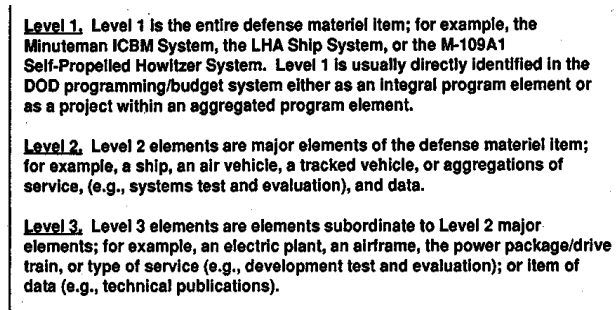


Figure 13-5 Work Breakdown Structure Level Identification

The contractor extends this structure to the cost account and work package levels (Figure 13-6). At that level, organizational elements are actually assigned to do the work. The work package must have discrete starting and completion points which are compatible with upper level schedules. The work package must be the responsibility of a single organizational unit.

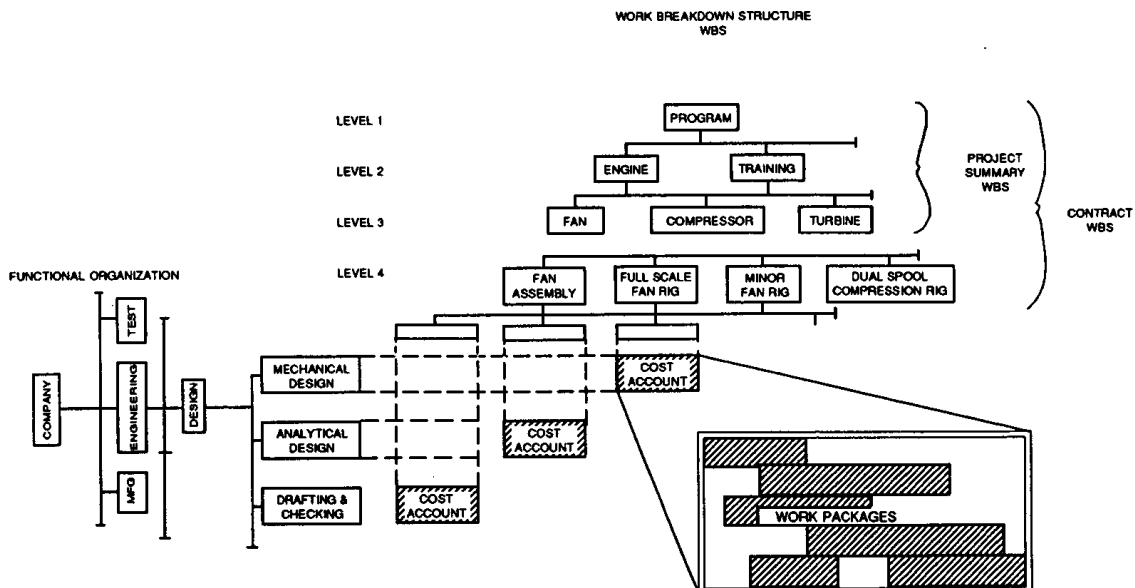


Figure 13-6 Work Breakdown Structure Extended to Cost Account and Work Package Levels

### Relationship to Contractual Schedules

The C/SCSC performance measurement baseline represents the contractor's internal work plan, the time-phased schedule expressed in dollars for performing the contract. This internal plan generally provides some cushion or slack calendar time with respect to the contract deliveries and milestones and anticipates typical problems such as late vendor deliveries and/or time required for rework of materials. If not understood, setback schedules can cause confusion. Negative (unfavorable) schedule variance may not affect contract delivery if sufficient slack is available in the schedule to absorb the delay. Schedule variance is expressed in dollars worth of work ahead or behind the plan and must be analyzed in conjunction with other schedule information such as network, Gantt, and line-of-balance charts. By itself, the C/SCSC schedule variance reveals no critical path information and may be misleading because unfavorable accomplishment in some contract WBS areas may be offset by favorable accomplishment in other areas.

### Implementation

Implementation of the C/SCSC begins with the requirement being placed in the Request for Proposal (RFP) using DFAR 52.234-7000, Notice of Cost/Schedule Control Systems. The offeror's proposal is then evaluated in terms of its ability to meet the criteria. The contractor either offers to use a previously accepted system or to make changes in the existing system to attain compliance with the criteria. The negotiated contract will contain DFAR 52.234.7001, Cost/Schedule Control Systems.

When a contract is awarded to a contractor that has not previously demonstrated an acceptable management control system, the contractor's system is reviewed by the Government to ensure that it meets the criteria. Successful demonstration of the contractor's management control system generally results in a tri-service acceptance that remains in effect as long as the system continues to meet the criteria. In the case above, wherein the contractor had a previously accepted management control system and proposed to use it on the contract, the Government performs a Subsequent Application Review (SAR). The purpose of the SAR is to determine whether the contractor is properly and effectively using this accepted system for the new contract. It is not a redemonstration of the previously accepted system.

Typical points of contention between the Government and Industry concerning C/SCSC implementation include: time required to implement, levels designated for management and reporting, variance thresholds, and system discipline requirements. These sensitive areas can affect the cost of implementing and operating a C/SCSC compliant system. The cost of C/SCSC, sometimes alleged to be excessive, has defied quantification. However, there is no dispute that improper implementation and excessive reporting requirements impose an unnecessary burden and additional cost on the contract. Knowledgeable C/SCSC personnel should be consulted during the preparation of the RFP, the data call and during negotiations.

### Reporting

There are no explicit external reporting requirements in the C/SCSC. The criteria require that contractors have and use effective internal control systems. Summary data from the internal systems are reported to the Government through the Cost Performance Report (CPR) as specified on the Contract Data Requirements List (CDRL).

### C/SCSC Summary

C/SCSC is the best tool available to assure that contractors have and use adequate cost and schedule management control systems. It provides better overall planning and control discipline on defense contracts. The associated reports summarize objective data from the contractor's internal system for both contractor and government managers to use. Improvements in contract management can be achieved by management attention to developing and using good cost and schedule management control systems and taking timely actions when problems are identified from the data generated.

### LINE OF BALANCE

Line of Balance (LOB) is a production control technique which combines features from a critical path scheduling time chart with a required delivery schedule, and presents in graphic form information relating to time

and accomplishment of production. It shows the delivery objective, sequence and duration of all activities required to produce a product, a progress chart of the current status of production items, and, from these charts, an LOB to show the relationship of actual component production to schedule.

LOB is most appropriate for assembly operations involving a number of discrete components and has proven most useful in production programs from the point when raw materials or incoming parts arrive, to the shipment of the end product.

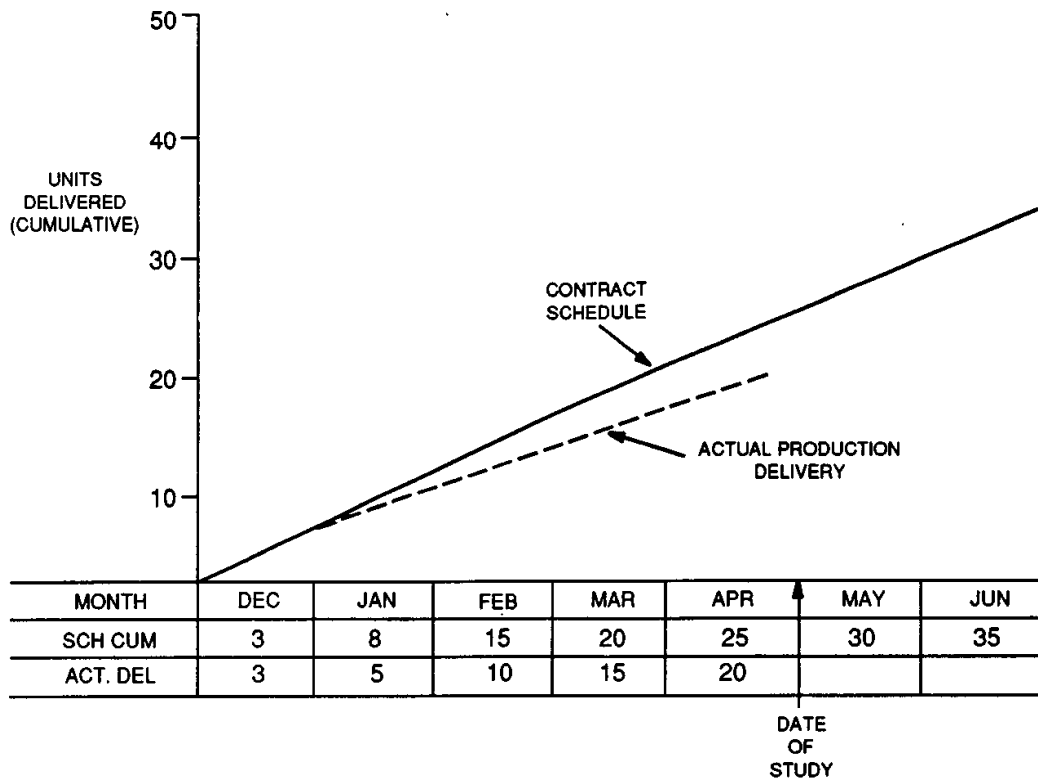
Without a computer controlled production process, Line of Balance does not lend itself readily to day-by-day updating, but a weekly or monthly check is usually frequent enough to keep the process on schedule. If the project falls behind schedule, management will know it, and know why, far enough in advance to make smooth adjustments.

Reporting to customers or top management is quick, inexpensive and graphic. The charts used for analysis and trouble shooting are suitable for at-a-glance status reporting. A set of clear, simple charts is easier to understand than a list of facts and figures, and charts are faster and more reliable than oral reports.

A Line of Balance study has four elements: (1) the objectives of the program; (2) the production plan, and a schedule for achieving it; (3) the current program status; and (4) a comparison between where the program is and where it's supposed to be. The first step in using LOB is to gather and organize the needed material for the three charts which comprise an LOB report. Once this is done you can "strike the line of balance" whenever necessary to keep track of the program.

#### Objective Chart

The objective chart is designed to display planned and actual deliveries in cumulative end items per unit of time. In Figure 13-7, for example, the delivery schedule calls for three items in December, five in January, seven more in February and five each month thereafter through June. The delivery schedule should realistically reflect attainable production capability taking into account learning associated with a new product (if this is an initial production activity) anticipated methods improvements, or other factors expected to influence productivity.

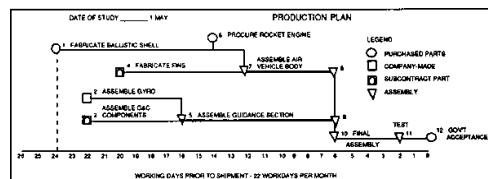


**Figure 13-7 Objective Chart**

The other curve on the Objective Chart shows actual delivery of parts. The horizontal difference shows how far actual deliveries lag scheduled deliveries in terms of time, the vertical difference shows the variance, in numbers of units, from schedule.

#### The Production Plan

Following the development of the objectives, the second step is to chart the planned process of production. The production plan is a graphic flow chart of the operations required to complete a unit. Selected production activities are plotted against the lead time required before shipment. For example, Figure 13-8 illustrates the key plant operations in the manufacturing sequence of a rocket.



**Figure 13-8 Production Plan**

The production plan is developed by setting down the selected events and operations in their proper sequence, commencing at the point of delivery and moving backward through the entire production process. The

control points are numbered from left to right and from top to bottom as shown in Figure 13-8. This will usually result in four or more general sequential phases as follows: the final assembly process, preceded by major subassembly work, preceded by manufacture of parts, preceded by acquisition and preparation of raw materials and purchased parts.

In Figure 13-8, the receipt of purchased parts identified as event 1 must start 24 working days in advance of final delivery for that unit. The gyro components must enter the production stream at control point 2 on day 22, as must the guidance and control components at control point 3 in order to assure start of the assembly of the guidance section (event 5) on day 16. If the required material or number of parts is not at each control point or any critical event in the production flow of a unit is not started on time (or completed on schedule), the delay is symptomatic of a problem which should be investigated; corrective action should be taken to forestall continuing delays and late deliveries.

#### The Progress Chart

The progress chart, example shown in Figure 13-9, pertains to the status of actual performance and comprise a bar chart which shows the quantities of materials, parts, and subassemblies available at the control points at a given time.

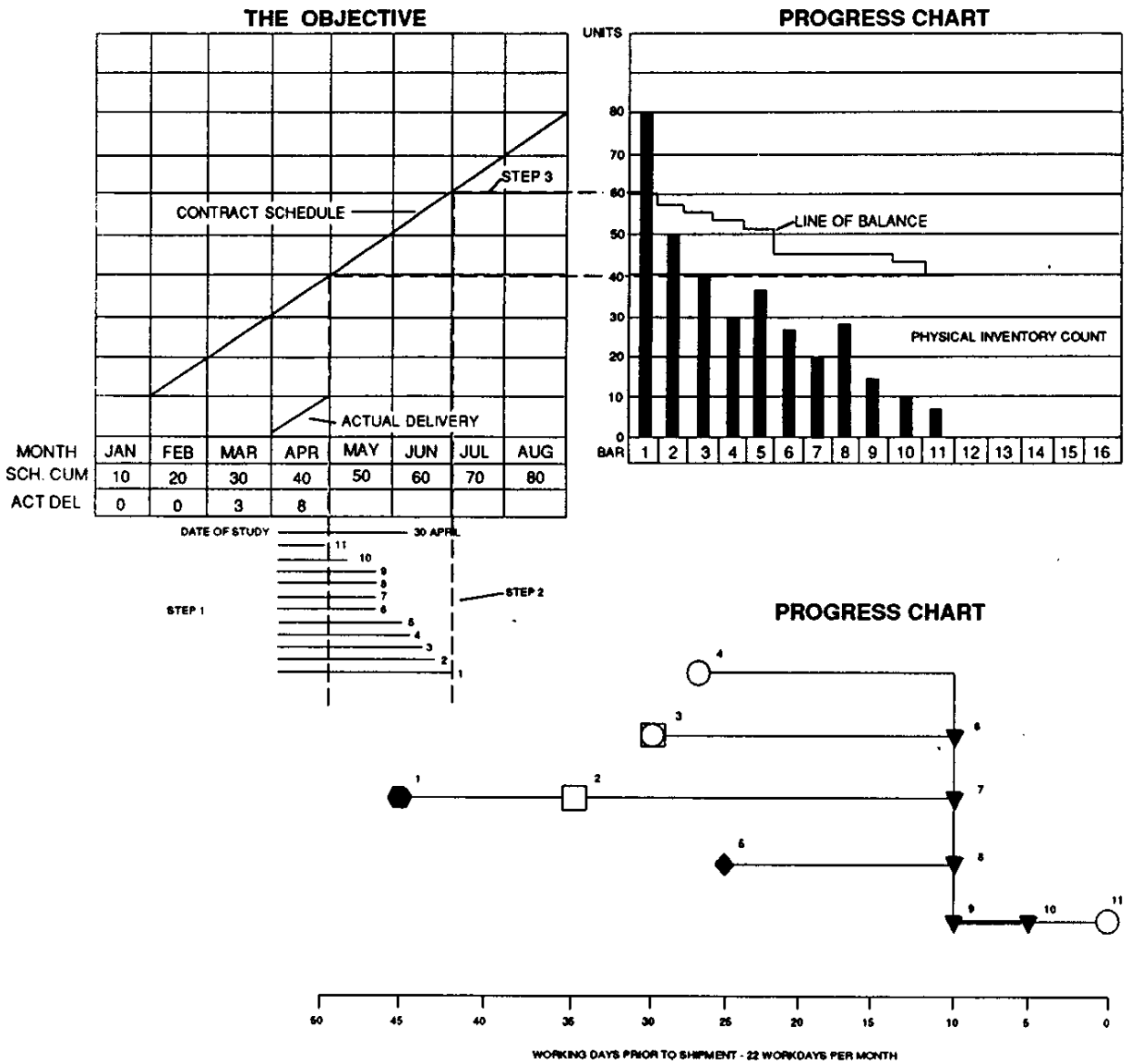


Figure 13-9 Line-of-Balance Chart

Production progress is depicted in terms of quantities of materials, parts, and subassemblies which have passed through the individual check points or control points of the production plan, including those contained in end items already completed. This information is derived from production records or accumulated by a physical inventory for each control point.

#### Comparison of Program Progress to Objective

Development of the objective chart, the production plan, and program progress chart completes the accumulation of physical information. There remains the task of relating the facts already gathered. This is accomplished by striking a “Line of Balance, (LOB)” which is the basis to be used for comparing the program progress to the objective.

The balance line quantity depicts the quantities of end item sets for each control point which must be available as of the date of the study to support the delivery schedule. In different words, it specifies the quantities of end item sets for each control point which must be available in order for progress on the program to remain in phase with the objective. Figure 13-9 is illustrative of the procedure for striking the LOB.

The balance line quantity depicts the quantities of end item sets for each control point which must be available at the end of the reporting period to support the delivery schedule. The required quantities are then compared with the actual completions by control point. Where the actual completions are less than the required quantity, this would indicate that there is a strong probability that deliveries will not be met at some future point. The timing of the potential delivery shortfall can be determined from the lead time data displayed in the LOB. If the behind schedule control point is 20 weeks flow time prior to final delivery, we would expect to see the impact in 20 weeks if corrective action is not taken.

Two final points should be noted. While the LOB technique offers insight into future delivery problems, the technique shows only where the problem is and does not characterize its nature. It is necessary for contractor or government management action to be taken to identify the causes and initiate appropriate corrective action. The second point deals with manner of presentation of the output products of the technique. For expository purposes we have emphasized the graphic mode utilizing charts. For large acquisitions it is often more appropriate to have the data provided in tabular form (particularly when the contractor utilizes computer analysis for preparation of the data). The key is to find the most cost-effective manner of portraying information for management action.